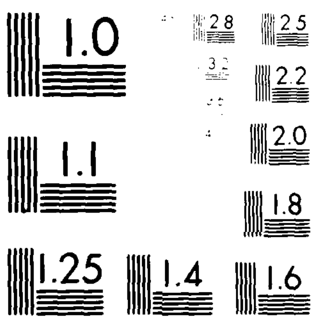
AD-A112 648 NAVAL RESEARCH LAB WASHINGTON DC F/G 20/14
UHF MARITIME SCINTILLATION MEASUREMENTS DURING SOS '81. A QUICK--ETC(U)
MAR 82 J M GOODMAN, A J MARTIN
UNCLASSIFIED NRL-MR-4762 NL

1 OF 1
AD A
112648

END
DATE
FILMED
04-82
DTIC



MICROCOPY RESOLUTION TEST CHART

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 4762	2. GOVT ACCESSION NO. AD-A112 648	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) UHF MARITIME SCINTILLATION MEASUREMENTS DURING SOS '81, A QUICK-LOOK REPORT		5. TYPE OF REPORT & PERIOD COVERED Interim report on one phase of an NRL problem. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. M. Goodman and A. J. Martin		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, DC 20375		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N; RR033-02-44; 0153-0-1; 0149-0-1/2
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Arlington, VA 22217		12. REPORT DATE March 30, 1982 13. NUMBER OF PAGES 34
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

The data acquisition effort associated with this research was partially supported under NRL work unit 0990-0-1. This report is essentially the same as a paper presented by one of the authors (J.M.G.) to the Internal URSI Conference held in Washington, DC August 13, 1981.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

UHF Scintillation
Maritime disturbance
Appleton anomaly
Earth-space propagation
Equatorial scintillation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Between 1 January and 15 April 1981, investigators at the Naval Research Laboratory participated in a comprehensive Study of Scintillation (SOS '81) in the American longitude zone using radio receivers installed aboard the US Navy Research Ship USNS Hayes (T-AGOR-16). Both UHF and L-band data were obtained using the transmissions from the Atlantic FLTSATCOM and from the existing complement of NAVSTAR/GPS

(Continues)

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

satellites respectively. This report describes the UHF scintillation data obtained during the Hayes expedition which covered geographic latitudes between 35°N and 50°S with considerable concentration in the Southern Hemisphere.

Strong scintillation at 250 MHz was observed (> 20dB) in the vast majority of nocturnal periods for which the magnetic dip angle (I) was within ±40° of the magnetic dip equator. This corresponds to roughly ±30° in geomagnetic latitude. This suggests that a substantial expansion in the equatorial UHF scintillation zone should be incorporated into existing models. It is thought that this new result may be circumstantially related to the enhanced solar activity during the period of observation.

CONTENTS

UHF MARITIME SCINTILLATION MEASUREMENTS DURING SOS '81
A QUICK-LOOK REPORT

1.0 INTRODUCTION

Equatorial irregularities are known to give rise to amplitude (and phase) scintillation of earth-space radiowaves. This phenomenon, analogous to the twinkling of stars in the optical part of the electromagnetic spectrum, has been the object of research for several decades. Many excellent papers have been published outlining the geomorphology and basic physics underlying this extremely rich and interesting phenomenon. [Aarons, 1978; Crane, 1974; Basu and Kelly, 1979; and recently Basu and Basu, 1981]. NRL and AFGL scientists have contributed to this field through direct (in-situ) measurements of ionospheric plasma characteristics in conjunction with ionospheric plume formation in the equatorial spread F environment [Szuszczewicz et al, 1980; Narcisi and Szuszczewicz, 1981]. In addition, a more fundamental understanding of equatorial scintillation has been derived from computational physics experiments undertaken by the NRL Plasma Physics Group [Ossakow, 1979] and a review of various spread F theories has been published [Ossakow, 1981].

Experimental studies detailing scintillation properties abound in the literature, and many interesting new results have been forthcoming during the current (now receeding) solar maximum epoch. Indeed, it was the result of the anticipated increase in scintillation at UHF in the equatorial zone in 1980-81 [Goodman, 1980] which led to the experimental program discussed in this paper.

The US Naval Research ship, USNS Hayes (T-AGOR-16) and shown in Figure 1, was scheduled to participate in various oceanographic studies during the first half of calendar 1981, and measurements were to be made throughout the Atlantic basin between Northern temperate latitudes to approximately Antarctica in the Southern hemosphere. This expedition provided a unique opportunity to examine the scintillation phenomenon over a wide range of latitudes under nearly solar maximum conditions.

Therefore plans were made to obtain data pertaining to the ionospheric personality in the maritime environment during the expedition. Accordingly, a Navy UHF Receiver, an AN/SSR-1, (the antenna component is shown in Figure 2) was installed on the Hayes along with a High Dynamics User Equipment (HDUE) GPS receiver. These systems would allow recording of UHF (249 MHz) transmissions of the Navy FLTBCST channel of the Atlantic FLTSATCOM (a synchronous tactical communication satellite located at geosynchronous altitude at a longitude of approximately 22°W) and the existing complement of NAVSTAR Global Positioning System (GPS) satellites. In view of a number of exigencies associated with delay in acquisition of the necessary GPS HDUE Receiver and the necesary system checkout, the GPS data was not available for the whole expedition and is not detailed herein. The UHF data were obtained for the length of the cruise and are the subject of this paper. Figure 3 shows the coverage pattern of the Atlantic FLTSATCOM, Figure 4 shows the track of the Hayes, and Figure 5 shows the geographic latitude variation. It is clear that most of the expedition was concentrated in the Southern hemisphere.

Manuscript submitted January 5, 1982.

2.0 EXPERIMENTAL OBSERVATIONS

To our surprise the occurrences of nocturnal scintillation were detected much earlier (i.e., at higher geomagnetic and geographic latitudes) than anticipated. The first occurrence of nocturnal scintillation (greater than 30 dB) was evidenced on 7 January 1981, the seventh day of the cruise. This was at 23.33°N, 46.97°W in geographical coordinates and at an approximate geomagnetic latitude of 34°N. This was of course, not anticipated on the basis of predictions. Evidently solar maximum conditions (the international sunspot number was "only" 89 on 1-7-81 but its long-term average was higher than this) had enhanced the zone of scintillation occurrence. This is of course, an heuristic deduction.

Figure 6 is an example of a record of UHF scintillation for Julian Day 61/62 (2-3 March 81) between 2300 GMT and 0600 GMT. Scintillation was deep but not totally continuous (sharp breaks were evidenced). The center of the chart (0200 GMT) is approximately midnight LMT. It is noteworthy that the AN/SSR-1 receiver experienced heavy "fault" activity during the scintillation. This is important for communication purposes.

Analog tape and strip charts were obtained during the course of the expedition. They were returned to NRL for processing.

3.0 DATA ANALYSIS AND PRESENTATION OF RESULTS

3.1 Geographical Variation

The field data were time-tagged every 15 minutes for the entirety of the 104 days of the Hayes expedition and scaled for maximum fade level and peak-to-peak scintillation over each 15 minute interval. This was done to survey the data prior to the specification of high interest regions for detailed processing, including spectral analysis and correlation of scintillation events with communication system default indications, which were also recorded.

Figure 7 is a plot of the maximum quarter-hourly UHF peak-to-peak scintillation (dB) observed between day 1 and day 104 of the expedition. Figure 8 is the maximum quarter-hourly UHF fade depth (dB). Upon comparison with Figure 5 it is clear that there is a paucity (indeed non-existence) of scintillation when the ship was above 23°N or below 38°S, but there was strong scintillation within these latitudes.

Figure 9 and 10 show the daily variation of the maximum quarter-hourly peak-to-peak scintillation (dB) and fade depth (dB) respectively. The circles represent the amount of scintillation with radii being proportional with the magnitude which ranged between 0 and about 40 dB.

Of some interest also, is the geographical distribution of scintillation duration. This is depicted in Figure 11. In this case we have presented in graphical form circles whose radii are proportional to the number of quarter-hourly intervals for which the scintillation exceeded 20 dB. The maximum circle dimension corresponds to roughly 32 intervals (8 hours). It is noteworthy that there were 51 days during the 104 day cruise for which scintillation exceeded 20 dB for at least one (1) quarter-hourly interval. Overall about 200 hours of scintillation ($\geq$ 20 dB) was encountered. This corresponds to about 7% of the total observation time including latitude zones where scintillation would not be expected, and daytime periods where scintillation is scarcely observed.

Returning to Figures 9 and 10, we note that within the scintillation zones there are breaks in occurrence of scintillation. In all there were 65 days in which scintillation was observed and 13 days for which scintillation did not occur within the discerned scintillation zone, (the Hayes being within the scintillation zone approximately 78 days). Thus, nocturnal scintillation within the zone occurred on 84% of the "opportunities". The reason for these periods of no scintillation is not known.

3.2 Organization of Data by Geomagnetic Dip Angle

Figures 12 and 13 are plots of the maximum daily quarter-hourly values of peak-to-peak scintillation (dB) and scintillation fade depth (dB) respectively. Although the number of data points is sparse in the Northern hemisphere, certain tendencies are clear. First, there is a sharp cut-off of scintillation when the dip angle (I) of the geomagnetic field exceeds 40° in absolute value. Secondly, there is a tendency for the scintillation to be somewhat diminished at the dip equator itself. This would have been predicted based upon past studies.

Figure 14 depicts the duration of strong ($\geq$20dB) scintillation for each day organized in terms of magnetic dip angle. Aside from the manifestations of the $|I| > 40°$ cut-off, there is no obvious pattern. The greater scatter in the Southern hemosphere may simply be the result of more opportunities in that region.

3.3 Diurnal Variation of Scintillation

There is also a wide variation in the behavior of scintillation with respect to the diurnal cycle. Figure 15 shows a more typical example of the quarter-hour fading range with respect to the mean signal level. Figure 16 is the magnitude of the fading range (peak-to-peak in dB). Figure 17 shows that scintillation occurrence during the night may be quite erratic.

3.4 Distribution of Scintillation Depth

Two types of distributions typically occur, but again there are wide variations. The more distinctive types are shown in Figures 18 and 19. Figure 18 shows essentially an "on-off" type of scintillation; whereas Figure 19 shows the two equally probable distributions sometimes occur on a given day, one corresponding to somewhat moderate fading amplitude and the second corresponding to strong scintillation. There was virtually never a situation for which only moderate fading was observed on any given day.

4.0 DISCUSSION OF RESULTS

The strong intensity of the UHF scintillation observed during the Hayes expedition precludes specification of an unambiguous diurnal and geographical distribution of equatorial irregularities responsible for the effect. However, the expanded latitudinal distribution is quite noteworthy. The L-band signals from the GPS satellite obtained during a portion of the expedition may partially assist in the elucidation of the irregularity formations. In particular, since the Total Electron Content (TEC) of the ionosphere may be extracted from the GPS data, it may be possible to correlate depletion zones with the observed scintillation [Klobuchar, 1978; Yeh et al, 1979]. Of primary interest is the location of the crests of the Appleton anomaly in the Northern and Southern hemospheres. Since the scintillation amplitude is likely to be the product of ambient density and irregularity amplitude, scintillation might be expected to be larger near the crest than within or on the poleward sides. However, this is an heuristic deduction and not a rigorous argument. Nevertheless, it has been recently shown that GHz scintillation is abnormally pronounced near Ascension Island, not far to the east of the near-equatorial Hayes measurements [Aarons et al, 1981]. This intense scintillation is not replicated at similar geomagnetic latitudes away from the Atlantic basin.

According to the model of scintillation developed by Fremouw and Rino [1978], the scintillation index S_4 exhibits twin peaks, the midpoint of which lies on the geomagnetic equator. The diurnal pattern of this feature is illustrated in the sequence of Figures 20-22. (The plots are contours of scintillation index at fixed Universal times for the case of 250 MHz transmissions from FLTSATCOM located at 0^o, 23^oW. The shaded region is the zone for which S_4 is greater than or equal to unity according to the model. (Solar maximum conditions are assumed with the 10.7 cm solar flux index = 200, and K_p = 6). The model suggests that the S_4 = 1 condition is a relatively narrow bifurcated band of latitudes. On the other hand, the Hayes data indicates that the S_4 = 1 condition is significantly larger than this - perhaps encompassing virtually all of the South American latitude region. This discrepancy is now being scrutinized very carefully. It is remarked that in the American Sector the magnetic equator lies 12^oS of the geographic equator at 85^oW geographic latitude. Furthermore, the geomagnetic field strength is relatively lower in the American sector than other zones, say the Asian sector. These distinguishing features in the American zone make the results obtained during the Hayes expedition quite interesting.

For completeness, a comment on solar and magnetic activity is in order. Figures 23-25 show the International sunspot number (R_I), the 10.7 cm flux index, and the Fredericksburg "A" index respectively. It is clear that the solar activity is quite large during the observation period. However, the magnetic activity levels were not particularly large except on isolated occasions; its impact may have been minor. It has been suggested that whereas solar activity has a positive effect on equatorial scintillation levels, the impact of magnetic activity control is to diminish the S_4 index. If this is the case we have the situation for which values of both of the external "driving functions - R_I and A" serve to enhance scintillation around the equatorial zone.

Fejer et al [1979] have suggested that during solar maximum conditions the higher altitude of the F2 maximum (caused by enhanced electric fields) may cause more efficient mapping of strong irregularities to the Appleton (Equatorial) anomaly crest regions. These crests and their diurnal behavior have been discussed earlier by Anderson et al [1973]. The Appleton anomaly begins during the daytime (1100 LMT) and progresses toward the poleward direction (larger dip angles). The anomaly reaches its maximum development at around 2000 hours (LMT) with the crest nearest to the geographic equator being the greatest. At 0200 LMT the asymmetry reverses and the crest farthest from the geographic equator is greatest. Thus, the Northern hemisphere anomaly crest would be largest in the American zone prior to midnight and the Southern crest would be greatest after 0200 LMT. At around 2000 hours (LMT) the crests are predicted to reach $\pm 16^{\circ}$ dip latitude ($\pm 32^{\circ}$ dip angle). The current (Hayes) data show scintillation having a sharp cut-off close to a dip angle of $\pm 40^{\circ}$. This is not totally inconsistent. Furthermore, the Anderson theoretical study is based upon an R_z of 107 and the current results were obtained for somewhat higher solar activity levels.

ACKNOWLEDGMENTS

The authors would like to recognize the assistance of Mr. Chauncy Myers, Mr. L. Harnish, and Mr. John Stewart, all of NRL, and Messers T. Priddy, L. Quinn, V.B. Richards, S. Buisson, and T. Wilson of Bendix Corporation during various phases of the SOS'81 program. Finally a tremendous debt of gratitude is owed to Mr. H. Flemming who allowed us the opportunity to take part in the USNS Hayes expedition.

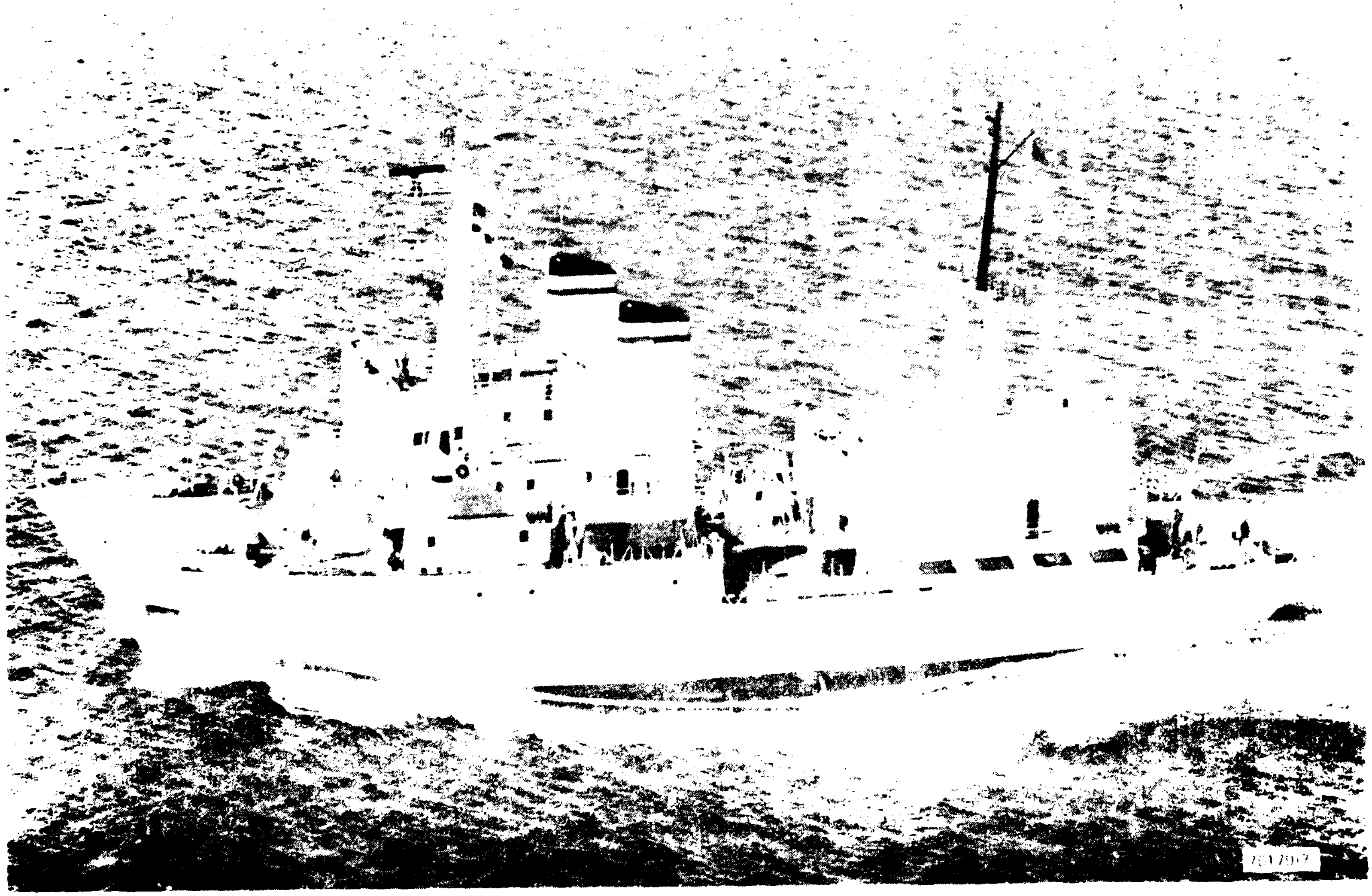
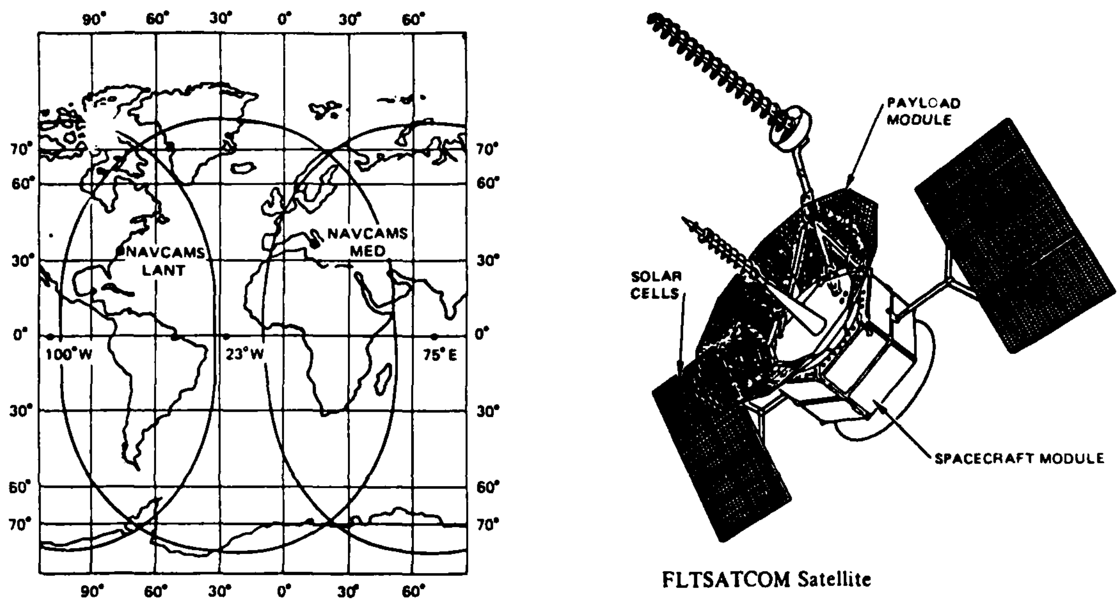


Fig. 1 - USNS Hayes (T-AGOR-16)

Fig. 2 - AN/SSR-1 Antenna system



FLTSATCOM Satellite

Fig. 3 - Coverage pattern of the various FLEETSATCOM satellites. The Atlantic FLTSATCOM is located at approximately 23°W longitude. The satellite is also shown on the right of the figure.

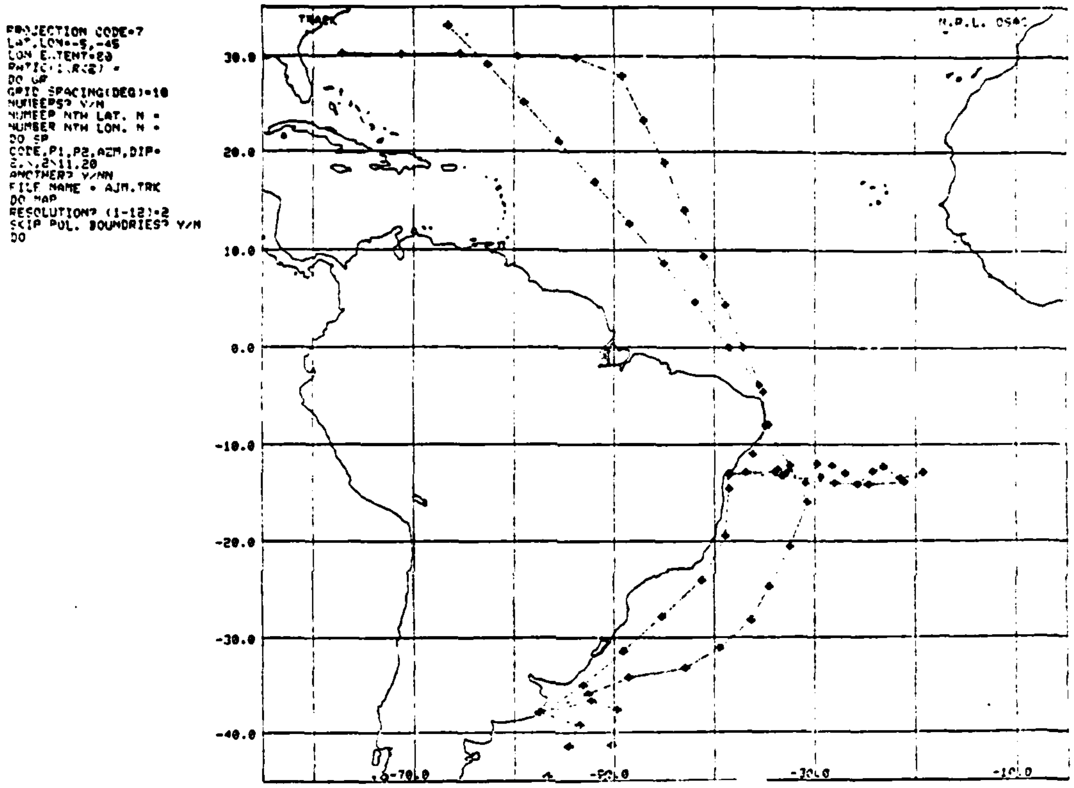


Fig. 4 - Computer representation of the track of the USNS Hayes between 1 Jan and 15 April 1981

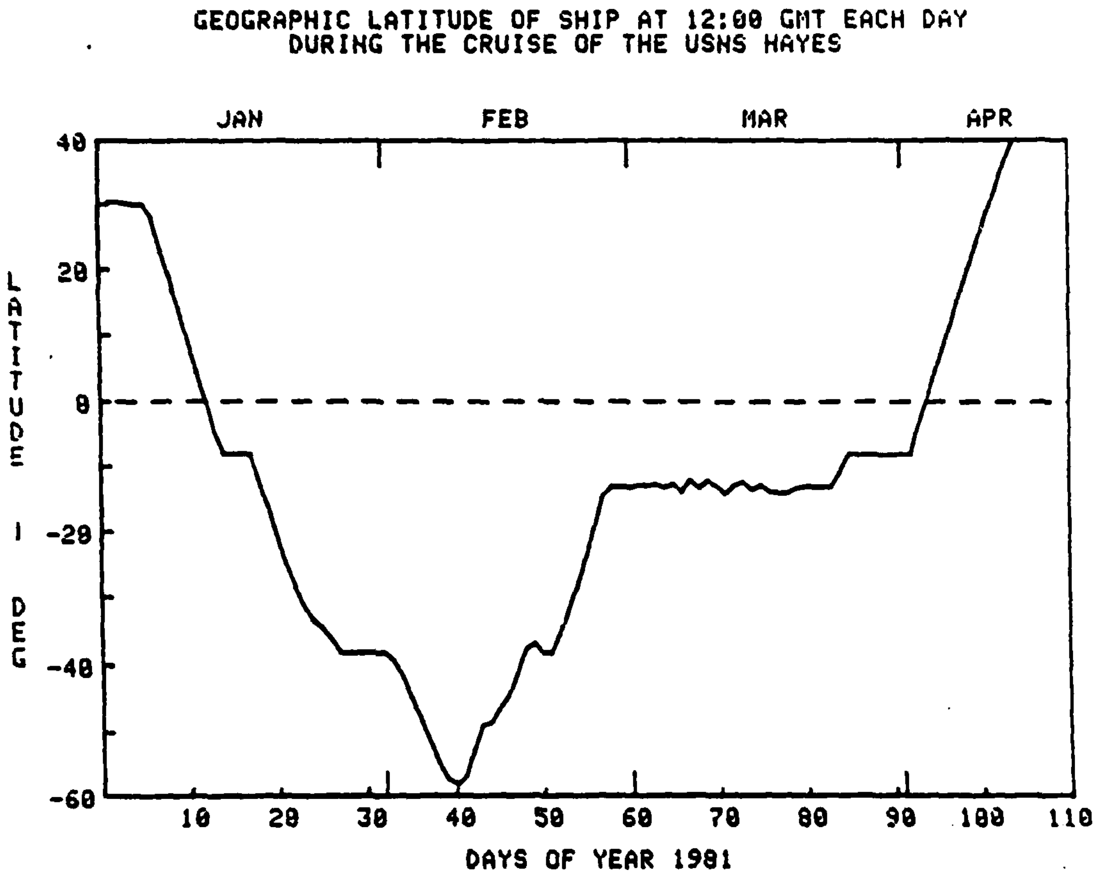


Fig. 5 - Geographical latitude variation of ship position

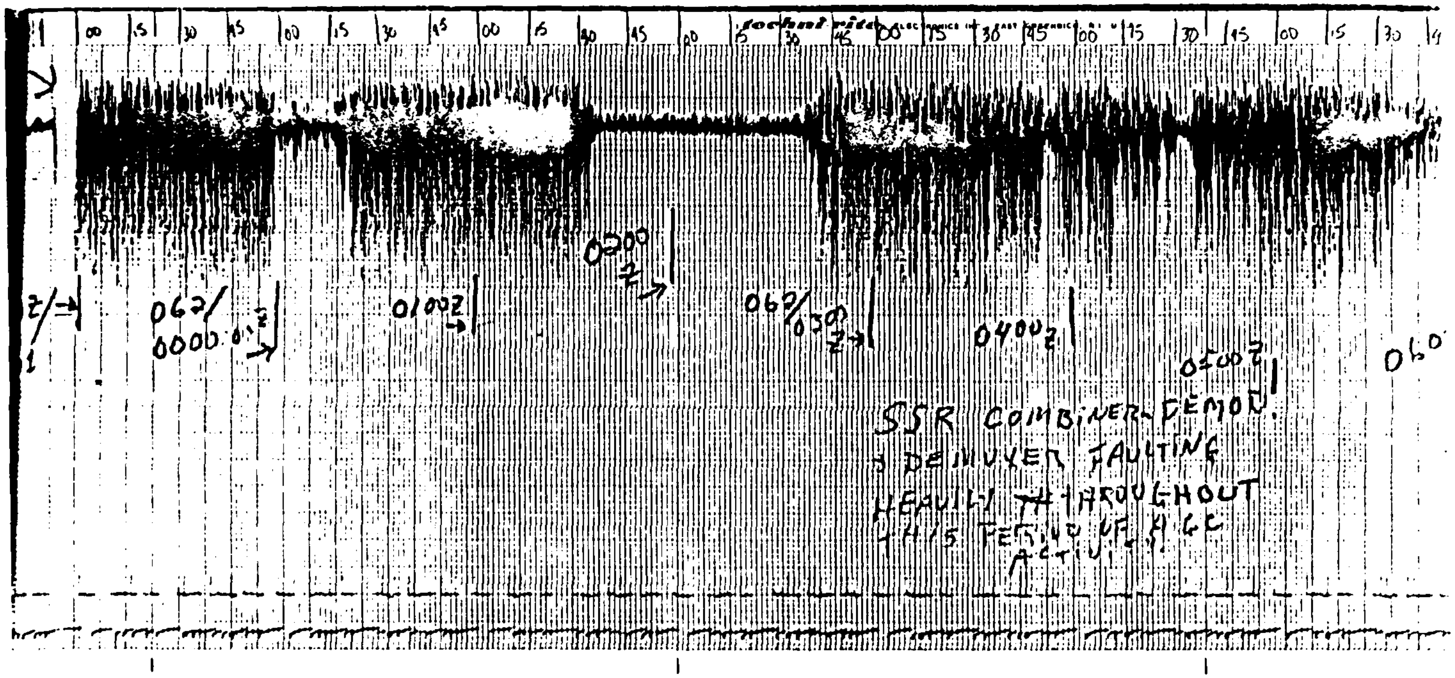


Fig. 6 - Record of UHF scintillation on Julian Day 61/62. The maximum fading experienced in this case is about 35 dB.

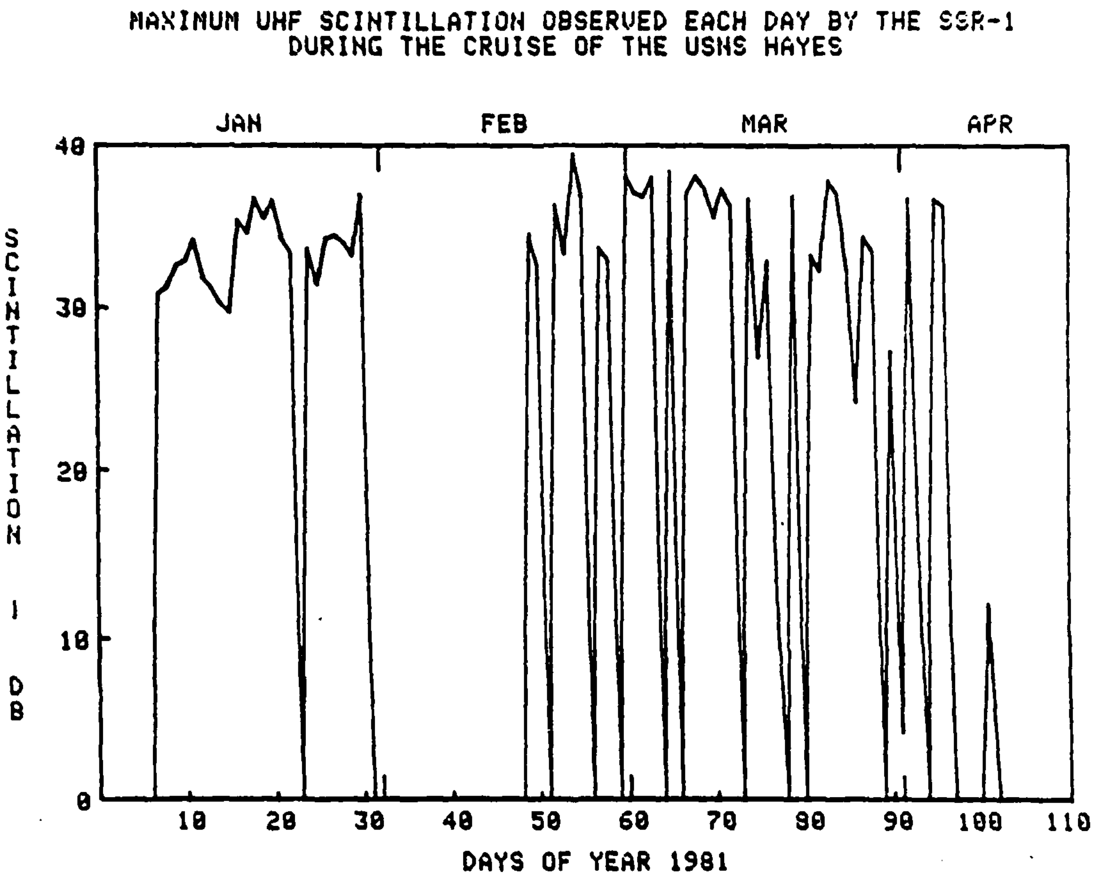


Fig. 7 - Maximum quarter-hourly UHF peak-to-peak scintillation (dB)

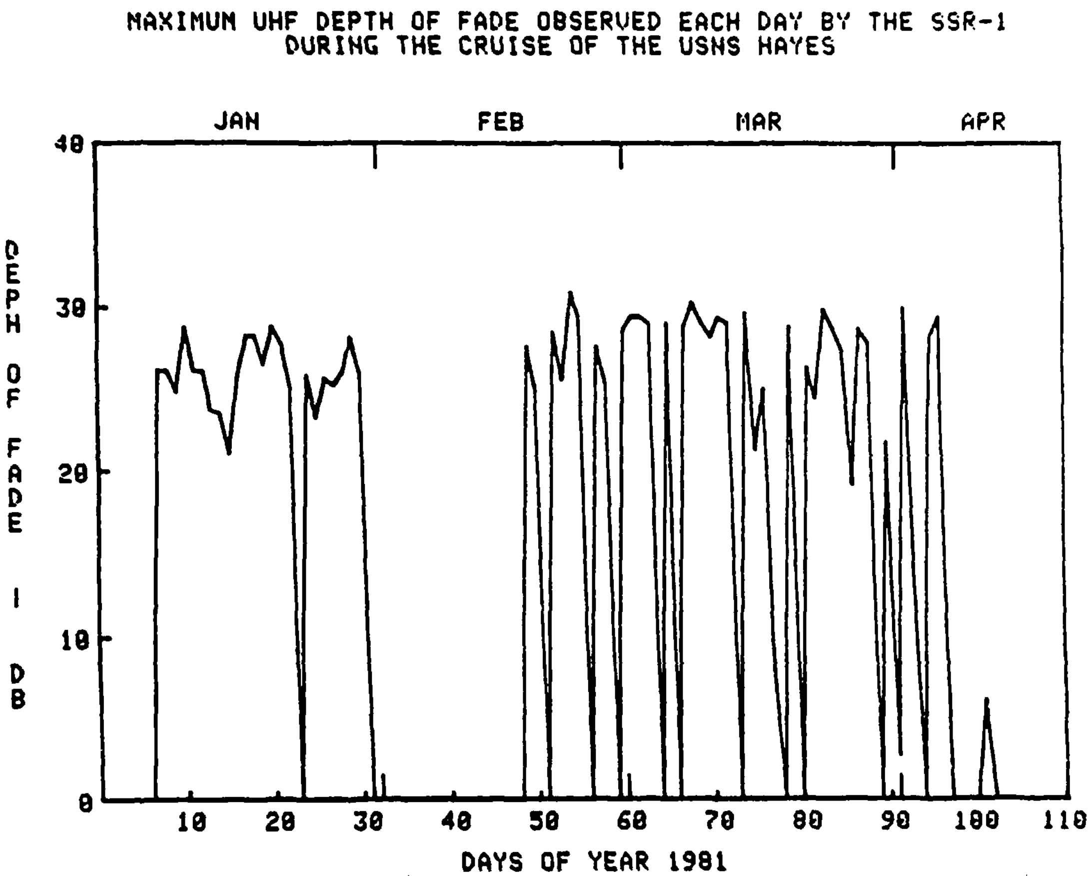


Fig. 8 - Maximum quarter-hourly UHF fading depth (dB)

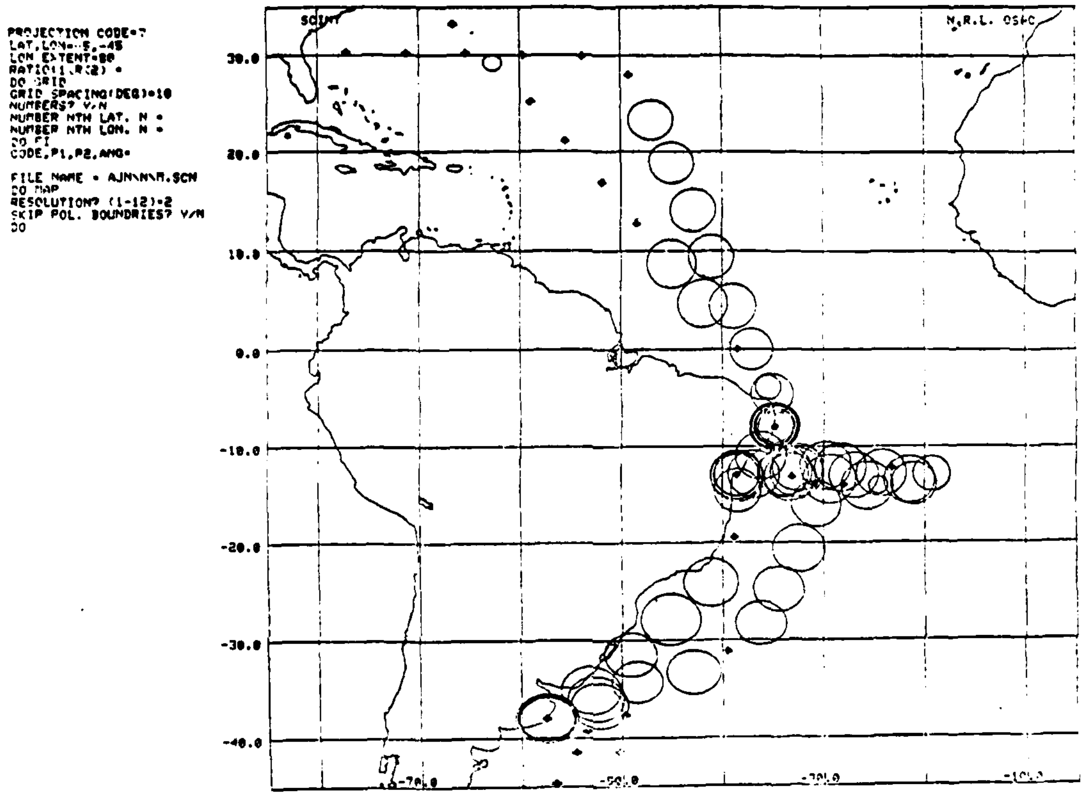


Fig. 9 - Representation of the daily variation of the maximum quarter-hourly peak-to-peak scintillation (dB). The circle size is proportioned to the magnitude of the scintillation and should not be confused with an "area" of scintillation. The actual data points are at the center of circles.

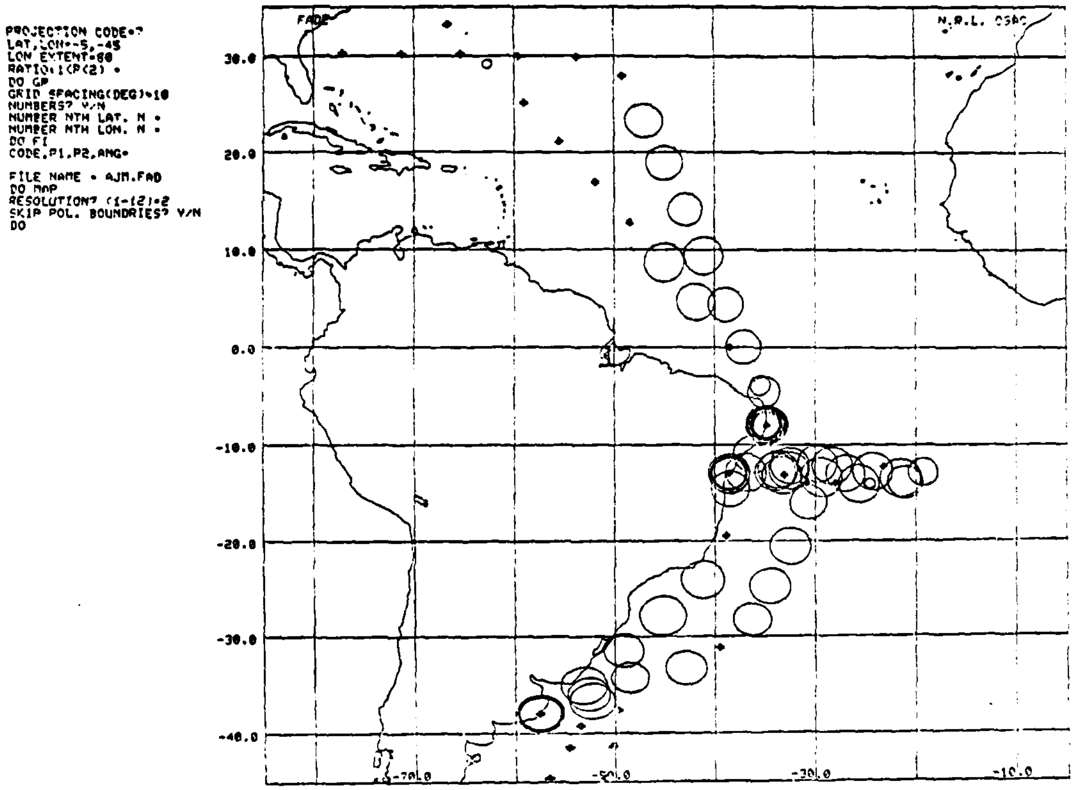


Fig. 10 - Same as for Figure 9, but Fade depth (dB) is considered

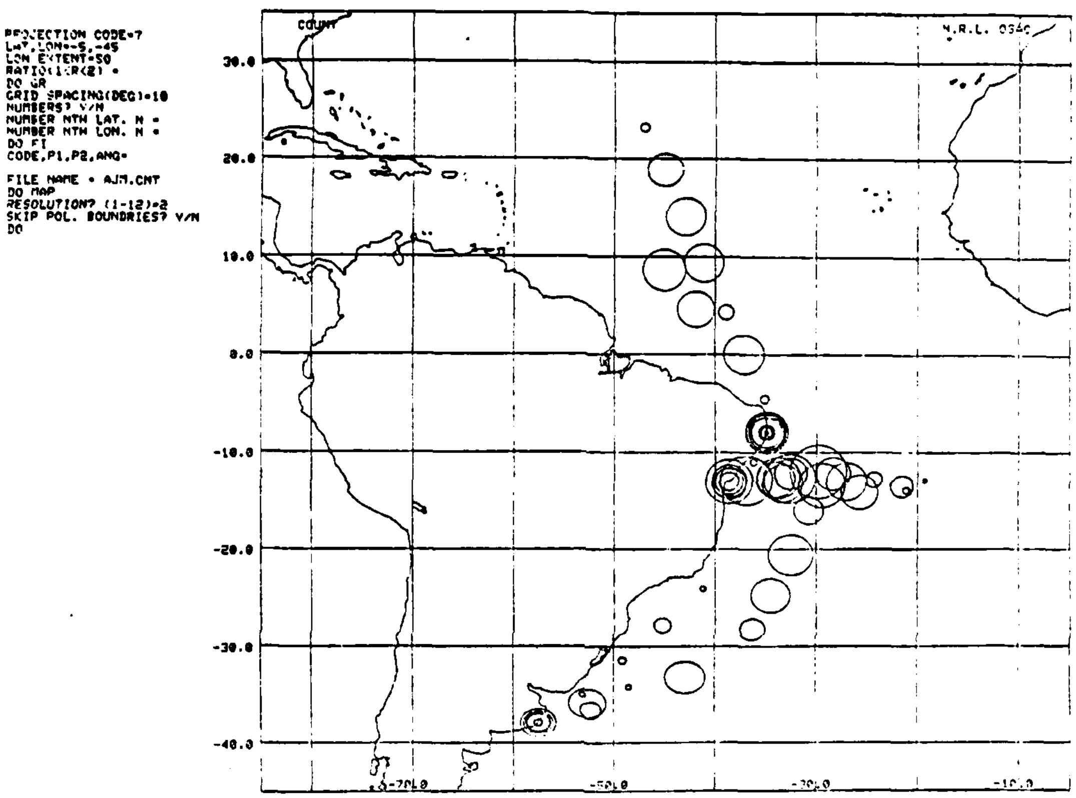


Fig. 11 - Same as for Figures 9 and 10 except the number of quarter-hour intervals for which the scintillation exceeded 20 dB per day is presented

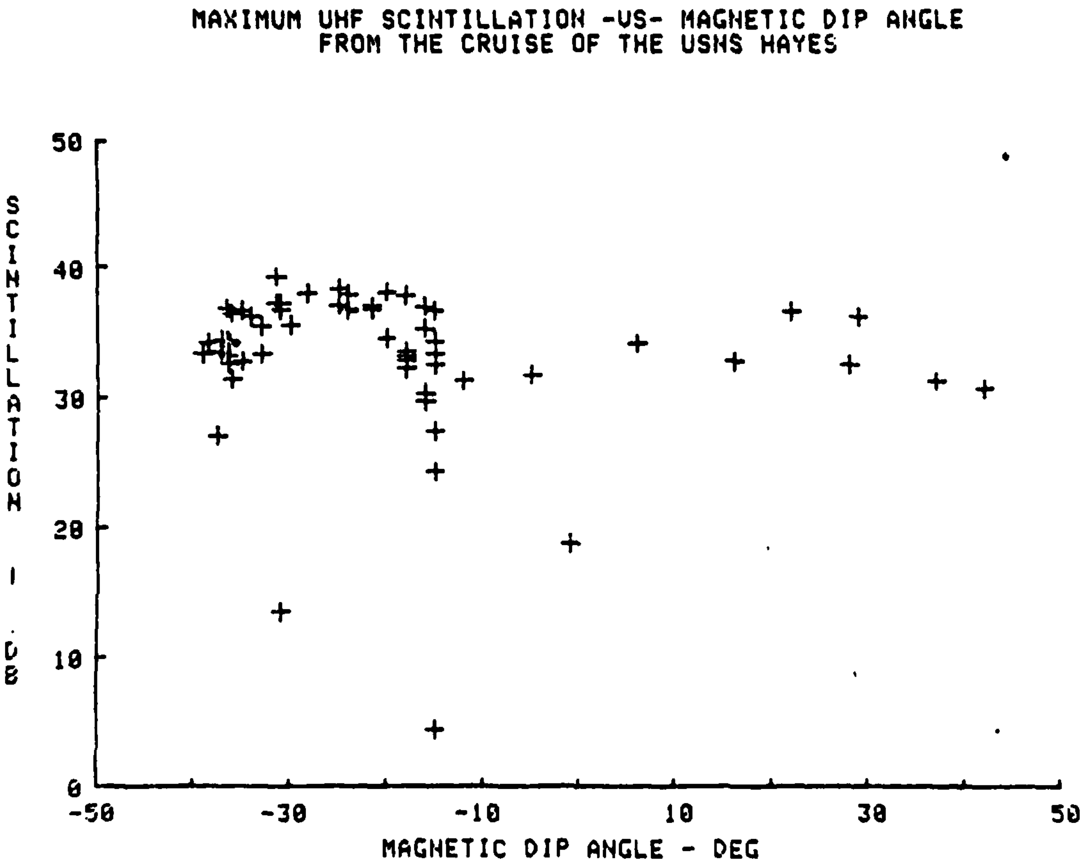


Fig. 12 - Maximum daily quarter-hour values of peak-to-peak scintillation (dB) versus magnetic dip (I) angle

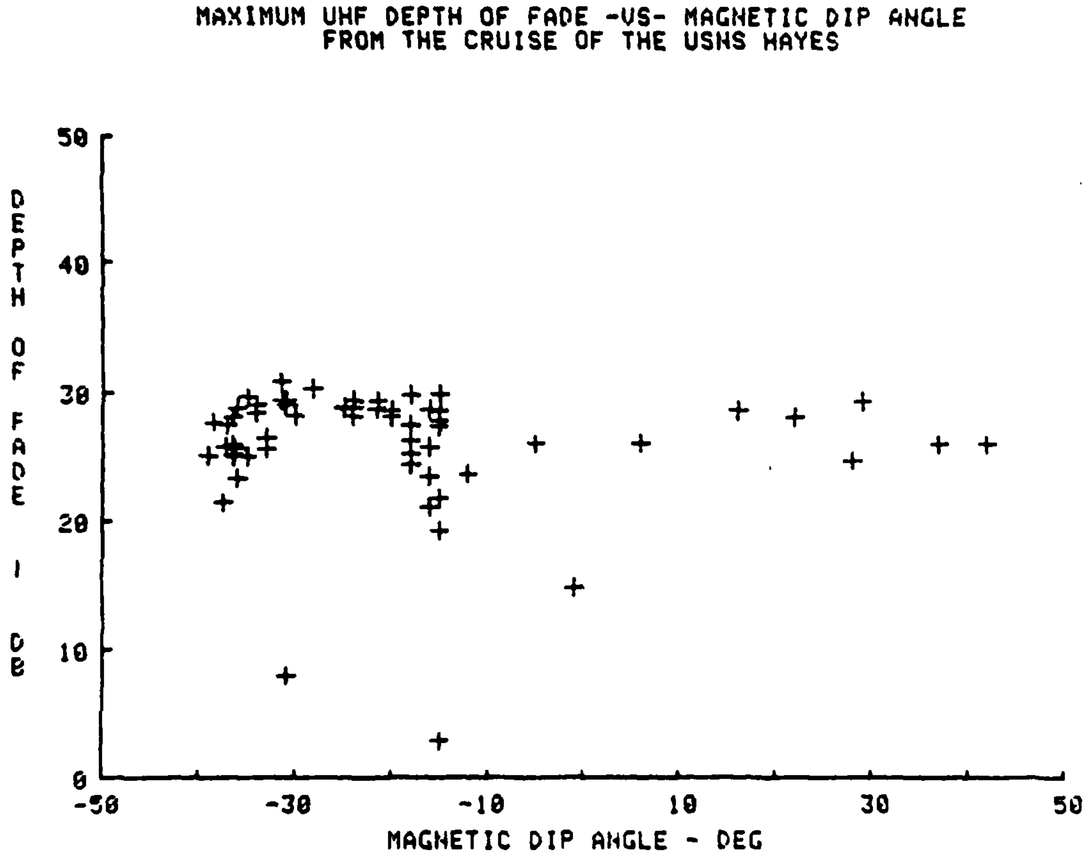


Fig. 13 - Same as Figure 23, except Fade depth (dB) is considered

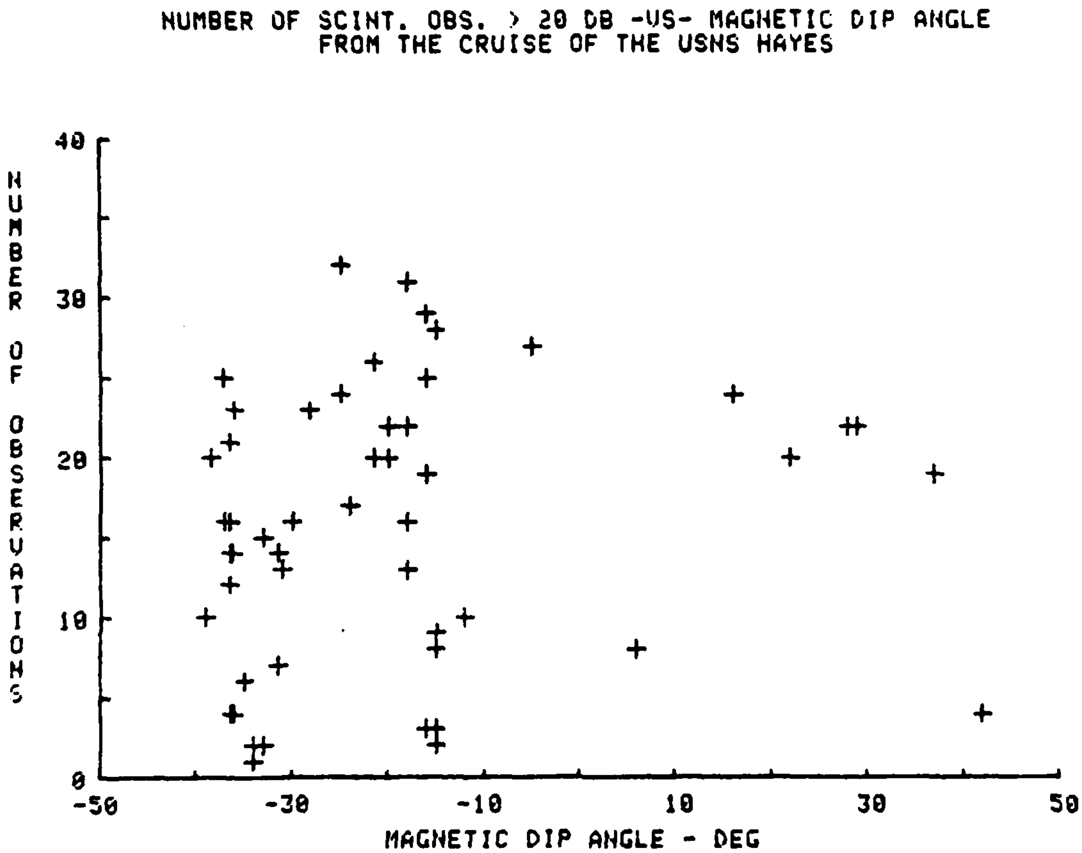


Fig. 14 - Same as Figures 12 and 13, except the number of occurrences for which the maximum quarter-hourly peak-to-peak scintillation exceeded 20 dB is considered

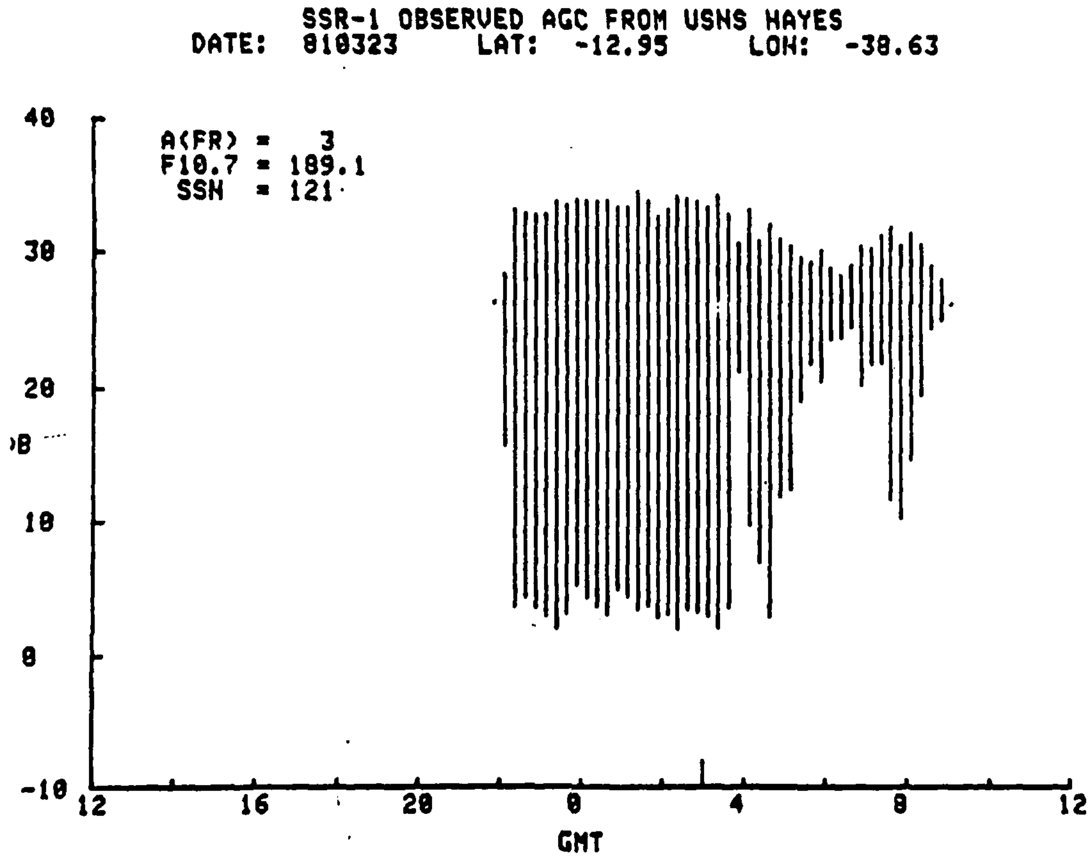


Fig. 15 - AGC level variations vs. GMT for March 23, 1981. The mean signal level is approximately 27 dB in this case (arbitrary dB scale)

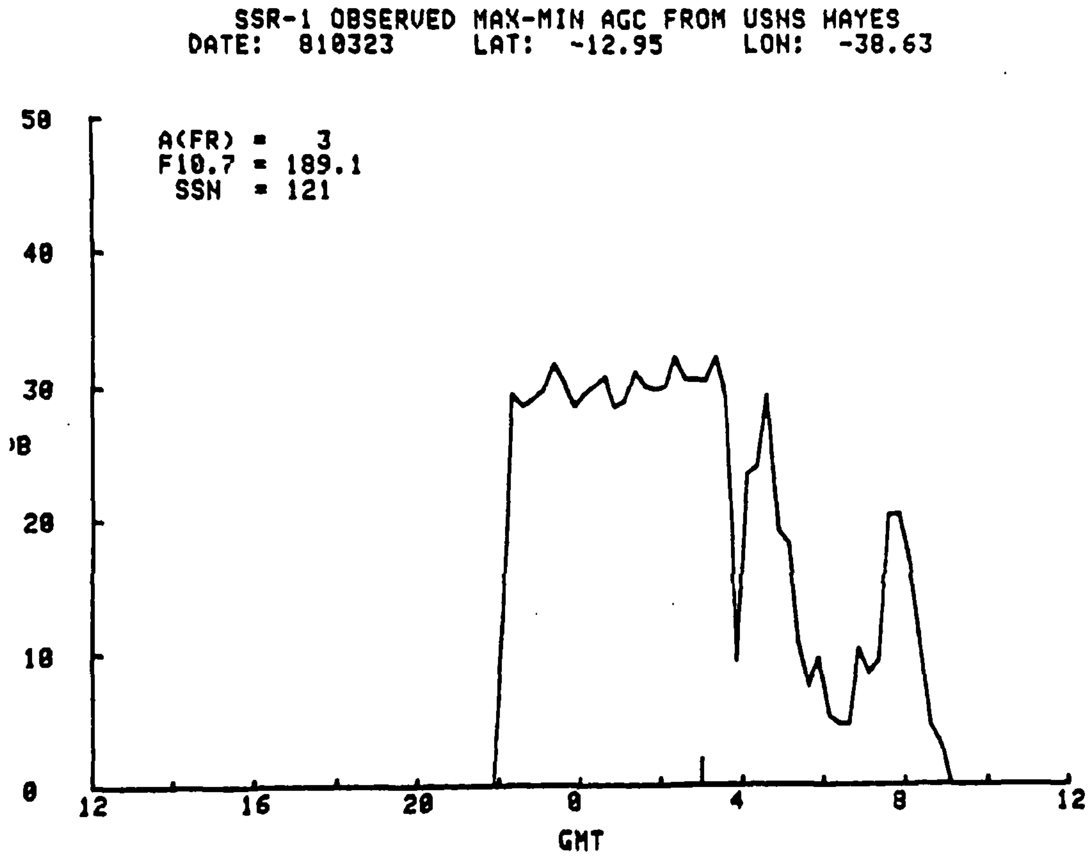


Fig. 16 - Range of AGC level variations (dB) versus GMT for 23 March 1981. The larger vertical "tick-mark" at 0300 GMT is local midnight. Note the sharp onset of scintillation approximately five (5) hours prior to midnight (shortly following sunset) and its gradual albeit erratic decay following midnight.

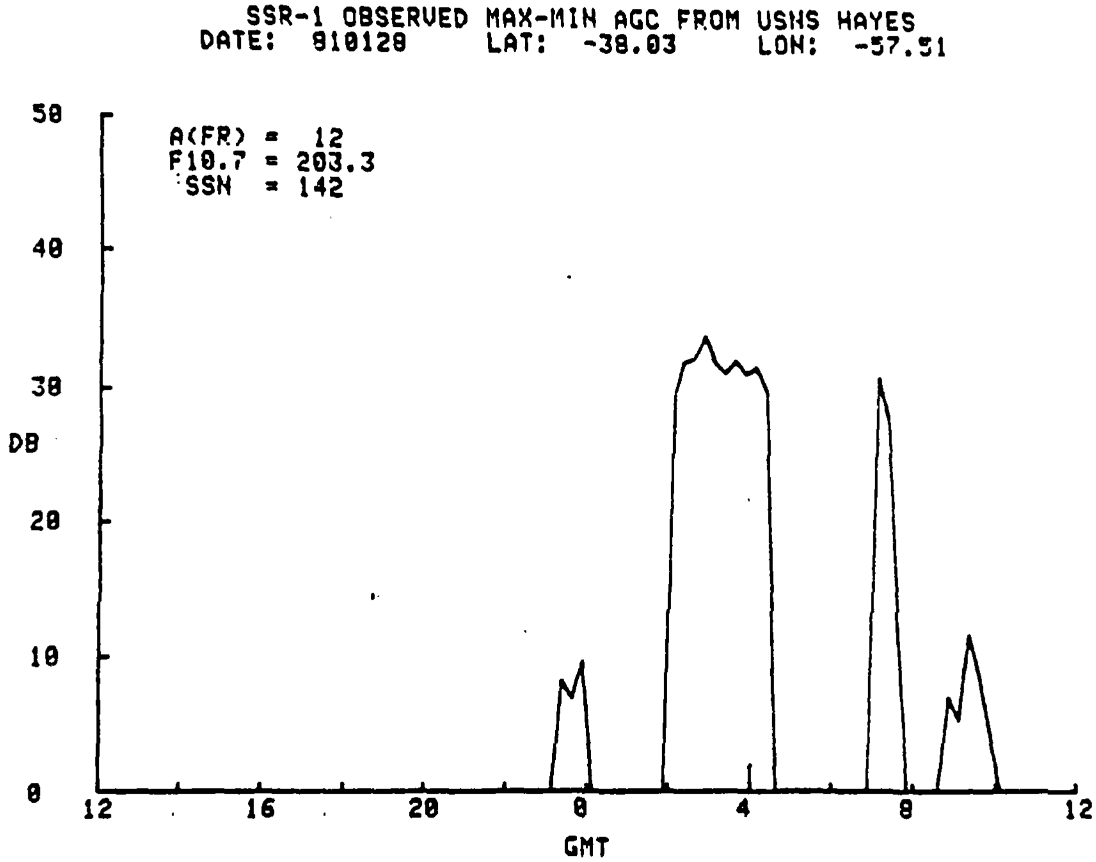


Fig. 17 - Same as Figure 16, except for January 28, 1981

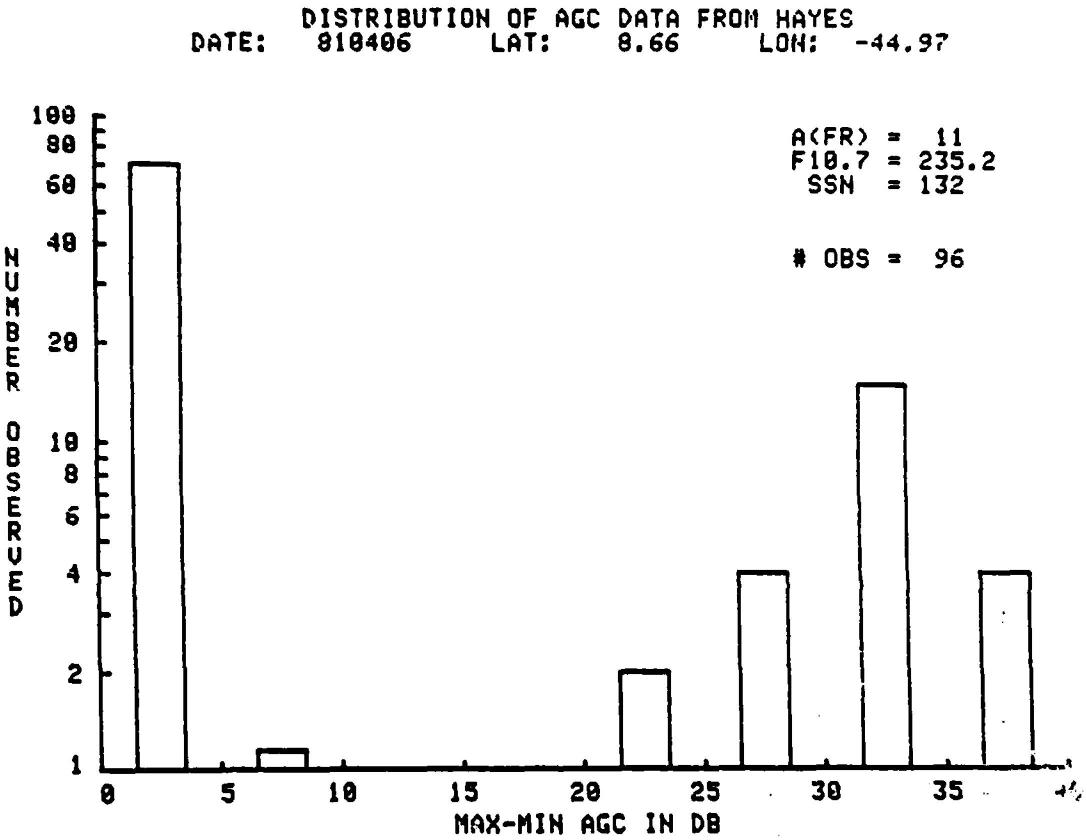


Fig. 18 - Distribution of fading depths for April 6, 1981

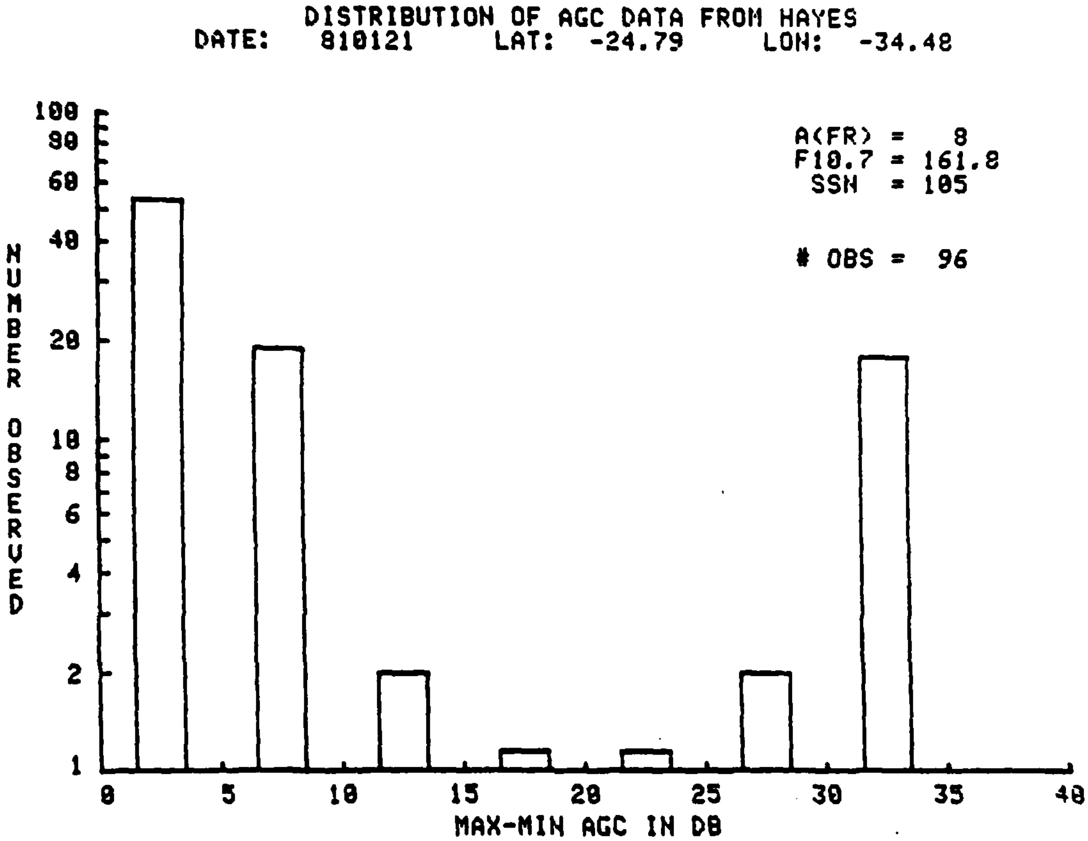


Fig. 19 - Distribution of fading depths for January 21, 1981

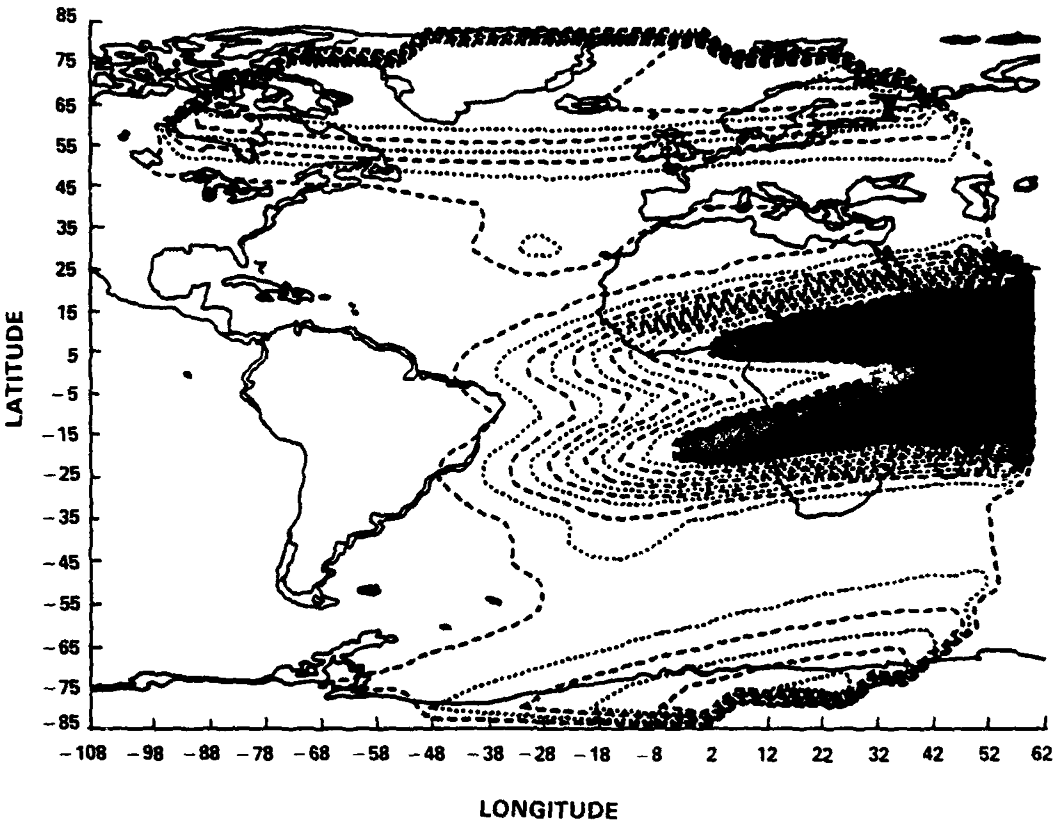


Fig. 20 - "Map" of UHF scintillation for 250 MHz transmissions from the Atlantic FLTSATCOM (23°W), under solar maximum conditions (15 Feb). The local time is approximately 2 hours following sunset at the sub-satellite point (2130 UT). (S_4 = 1 within the shaded region).

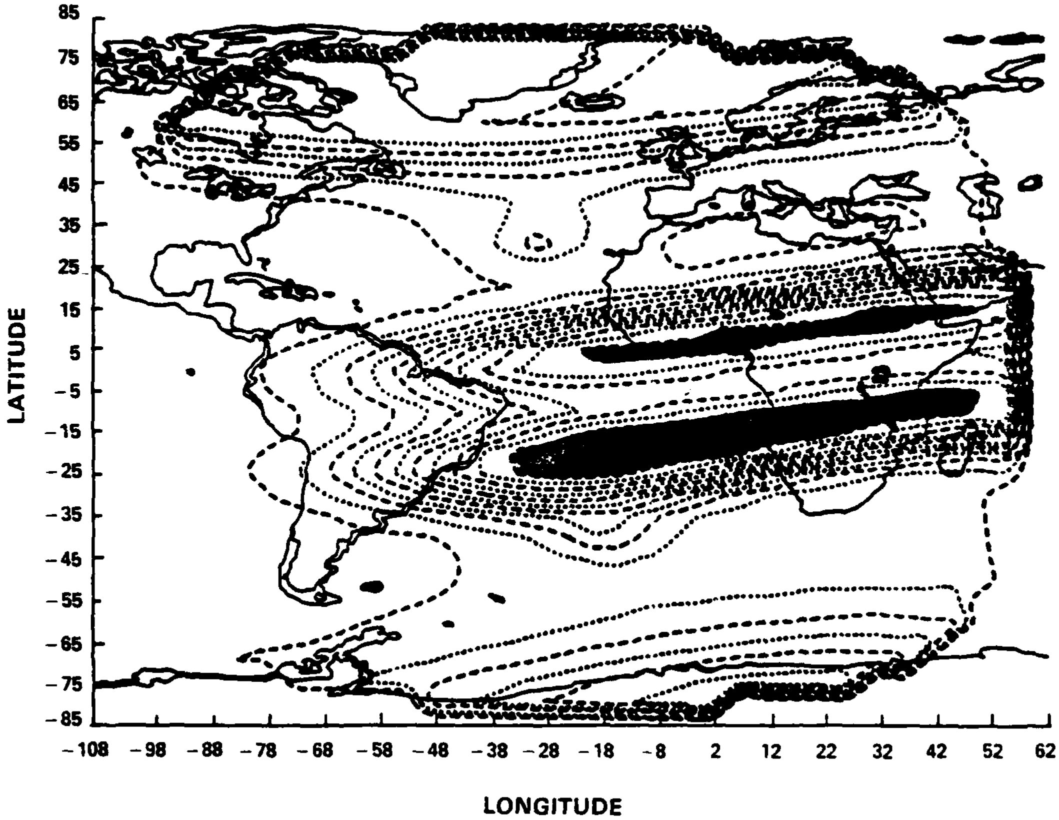


Fig. 21 - Same as 20, except the local time is about four hours after sunset at the subsatellite point (2330 UT)

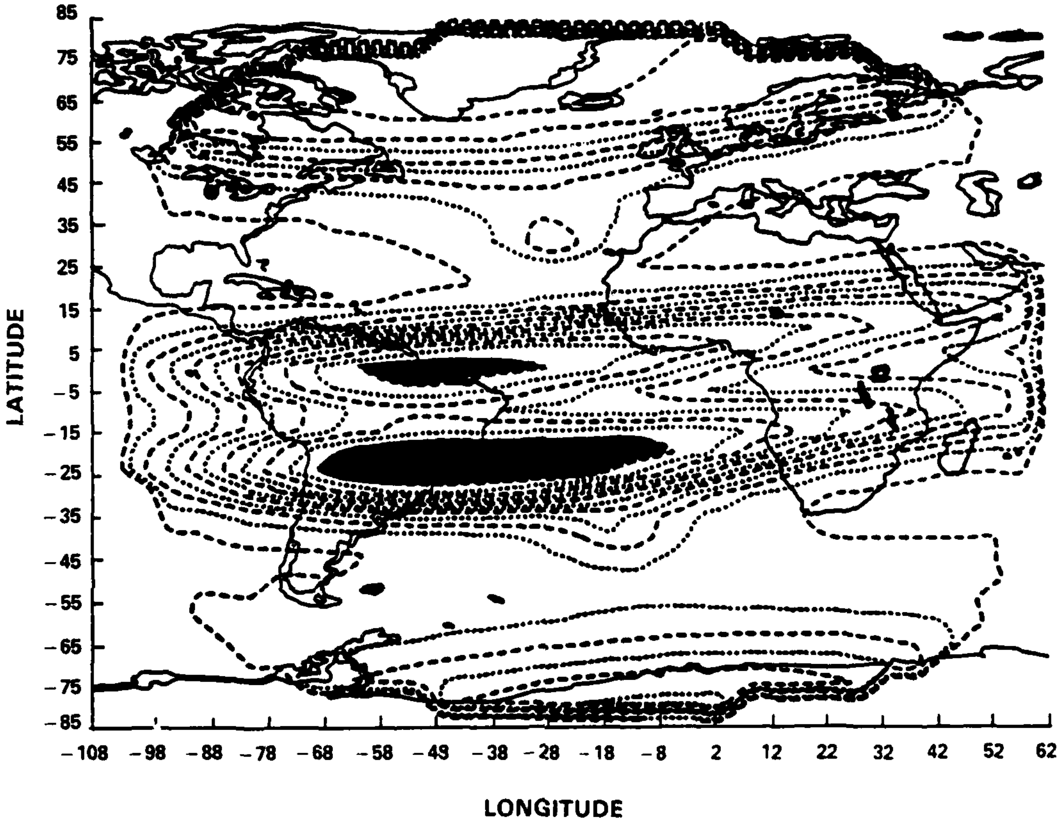


Fig. 22 - Same as 20 and 21, except the local time is approximately midnight at the subsatellite point (0130 UT)

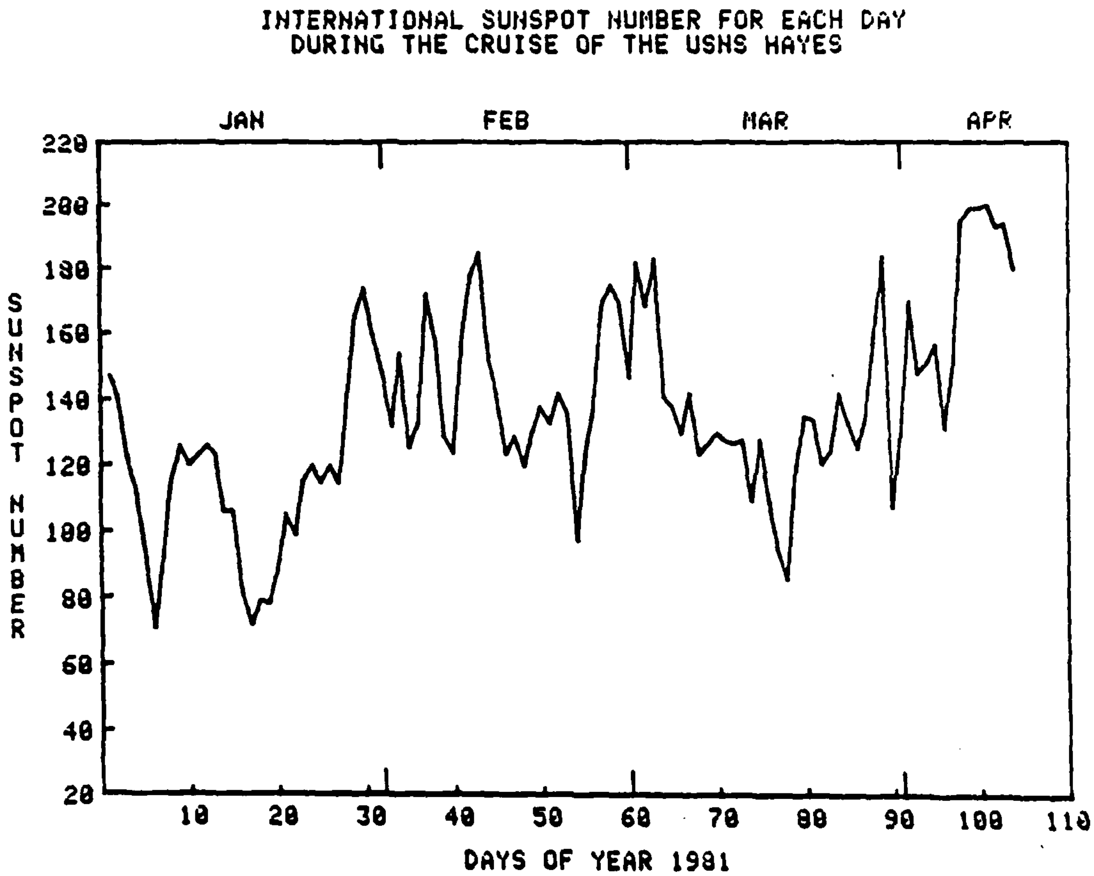


Fig. 23 - Sunspot Number R_I vs. day of expedition

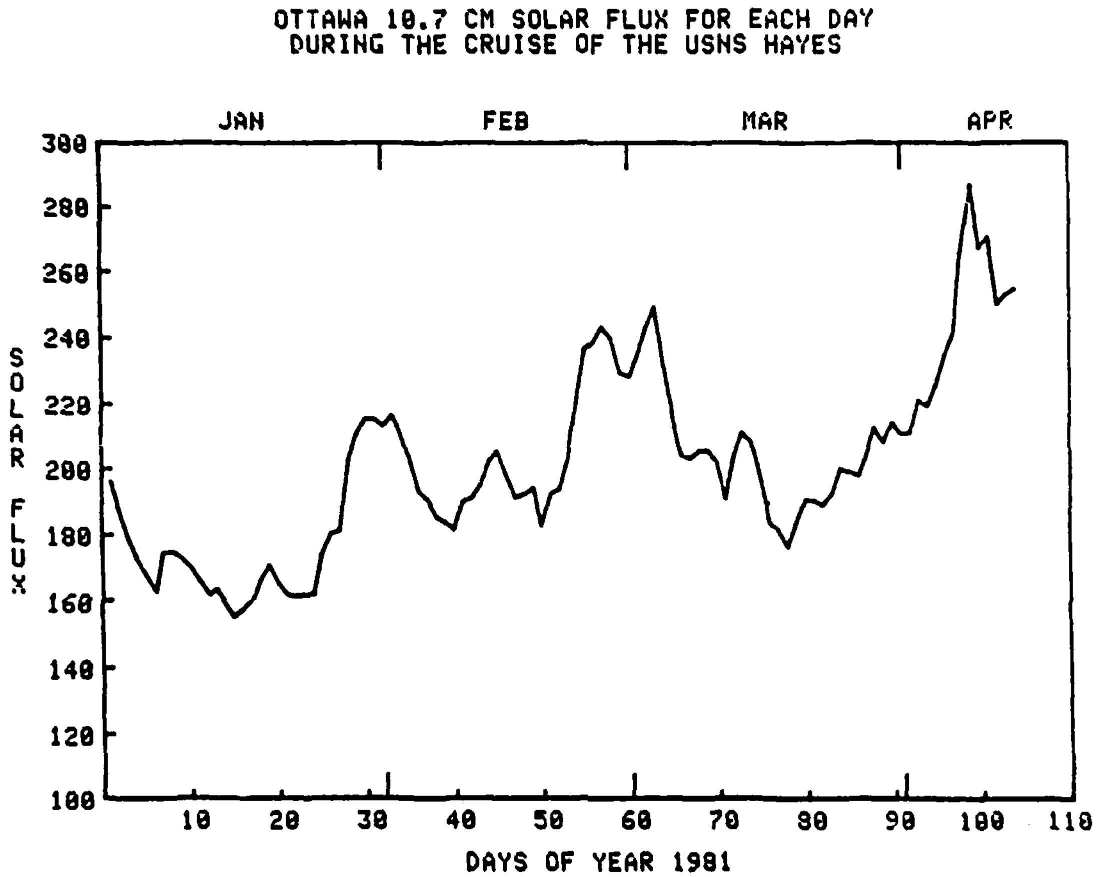


Fig. 24 - 10.7 cm solar flux vs. day of expedition

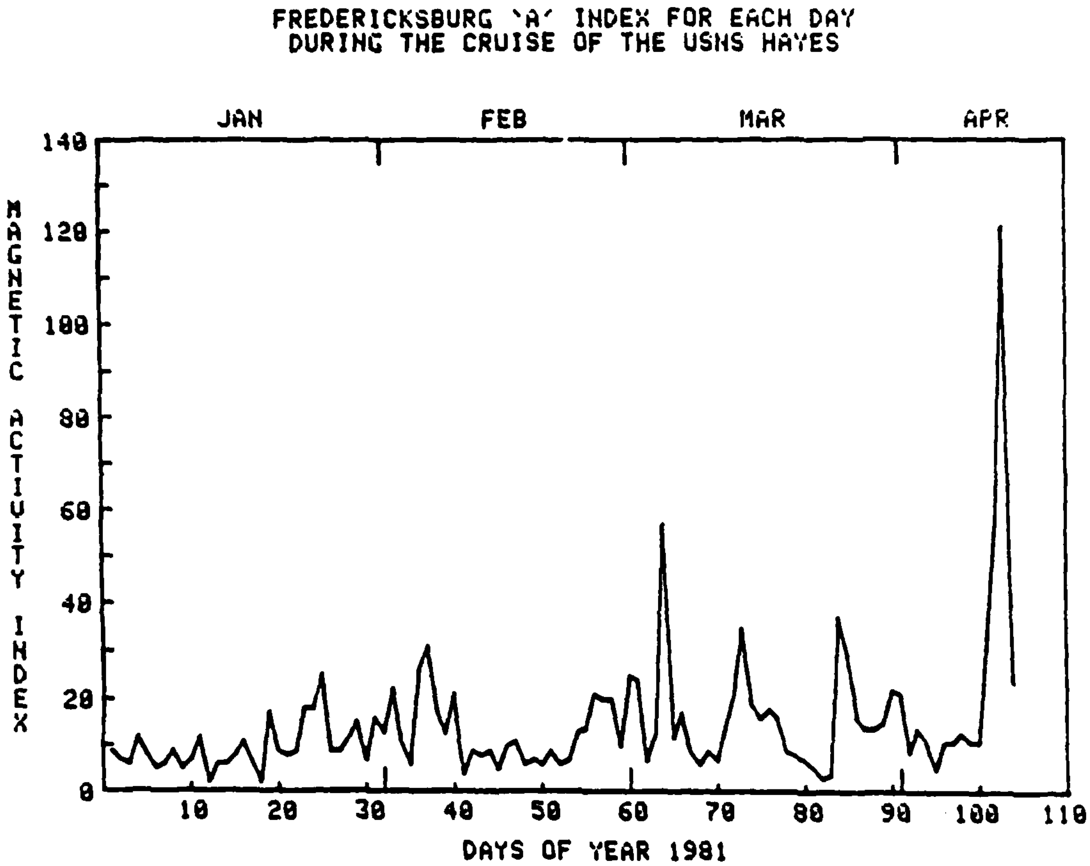


Fig. 25 - Magnetic activity index A_{FR} vs. day of expedition

REFERENCES

1. Aarons J., 1978, "Ionospheric Scintillations - An Introduction" in Recent Advances in Radio and Optical Propagation for Modern Communications, Navigation, and Detection Systems edited by J. Aarons, AGARD-LS-93, Tech. Edit. and Reprod. Ltd., London.

2. Aarons J., H.E. Whitney, E. MacKenzie, and S. Basu, 1981, Radio Sci. 15 (in press).

3. Anderson D.N., 1973, J. Planet. Space Sci., 21, 421.

4. Basu S. and M.C. Kelley, 1979, Radio Sci. 14, 471.

5. Basu S. and S. Basu, 1981, J. Atmospheric Terrest. Phys 43, (5/6) 473-489.

6. Crane R.K., 1974, "Morphology of Ionospheric Scintillation", Lincoln Lab TN-1974-29.

7. Fejer B.G., D.T. Farley, R.F. Woodman, and C. Calderon, 1979, J. Geophys. Res. 84 (A10) 5792.

8. Fremouw E.J. and C.L. Rino, 1978, "A Signal Statistical and Morphological Model of Ionospheric Scintillation" in Operational Modelling of the Aerospace Propagation Environment edited by H. Soicher, AGARD-CP-238. Tech. Edit. and Reprod. Ltd. London.

9. Goodman J.M., 1980, "A Resume of Anticipated *FLEETSATCOM* and *GAPFILLER* Scintillation Effects During the Peak of Solar Activity 1980-1982", in Vol 4 Solar-Terrestrial Predictions Proceedings edited by R.F. Donnelly, pp D1-D50, US Gov't Printing Office, Washington, D. C.

10. Klobuchar J.A., J. Aarons, E.J. Weber, R. Lucena, and M. Mendillo, 1978, URSI Abstract, Boulder, Co.

11. Narcisi R.S. and E.P. Szuszczewicz, 1981, J. Atmospheric Terrest. Phys. 43 (5/6) 463-471.

12. Ossakow S.L., 1979, Rev. Geophys. Space Phys. 17, 521.

13. Ossakow S.L., 1981, J. Atmospheric Terrest. Phys. 43 (5/6) 437-452.

14. Szuszczewicz E.P., R.T. Tsunoda, R.S. Narcisi, and J.C. Holmes, 1980, Geophys. Res. Lett, 7, 537.

15. Yeh K.C., H. Soicher, and C.H. Liu, 1979, J. Geophys. Res 84, 6589.

END

DATE
FILMED

04-82

DTIC